lowed this purpose to change materially the presentation of "the large essentials of plant life." "The effort is to include what has proper place in the education of *all* young people," and he distinctly excludes those special matters which are best relegated to agriculture, horticulture, domestic science, forestry, etc. In other words, we have here what the author believes all young people should know about plants as a general foundation for the subjects named, or even as a preparation for college botany. The present reviewer is in hearty accord with this educational theory, and he believes that in all well-considered schemes of education pure science must precede applied science.

The book is written in an easy, almost conversational style, and one wonders just how it is likely to be used by the ordinary teacher. It can scarcely be "recited" by the pupil, and possibly this may be a point in its favor. Perhaps this is why the author has added questions after the chapters, usually a feature of doubtful value, from the temptation it offers to the illy-prepared teacher to hold the book and ask the questions noted down before him.

Looking through the book, one is struck by a freshness of statement, showing that the author feels that he has a message for the high-school pupils of the country, and this continues with unabated enthusiasm from the first paragraph of the introduction to the closing paragraph of the book. It should do much to place high-school botany in this country upon a higher plane than it has ordinarily attained.

A NICE LITTLE DIATOM BOOK

One of the most attractive little books that we have seen in many a day is one entitled "Bacillariales" by H. v. Schönfeldt, and published by Gustav Fischer, of Jena. It is volume 10 of the series of booklets now in course of publication entitled "Die Süsswasserflora Deutschlands, Osterreichs un der Schweiz" and edited by Professor Doctor Pascher, of Prag. There are to be sixteen of these booklets, bound in limp cloth, each measuring about 11 × 19 cm. The book before us gives ten pages to structure, cell-contents, movements, reproduction, collecting, mounting and the literature of the group. Then follow 163 pages of systematic descriptions, the general treatment following that by Schütt in Engler and Prantl's "Natürlichen Pflanzenfamilien." Fourteen pages are given to the round diatoms (Centricæ), including eight genera and thirty-five species, while about 150 pages are given to the long diatoms (Pennatæ) in which are included about 40 genera and 390 species. These figures emphasize the statement often made that the round diatoms are mostly marine, and the long diatoms mostly inhabitants of fresh waters. Probably the truth is that in fresh waters we find many more long diatoms, because there are many more of them in the world at large, but this does not wholly account for the great disparity in numbers.

There are 379 cuts in the text, which must help the student greatly in his attempts to understand the structure and especially the markings of the cell-walls. A well-arranged index of scientific names closes this handy little book. One can not lay down this book without the wish that some day we may have something like it for this country.

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SPECIAL ARTICLES

SUSCEPTIBILITY GRADIENTS IN ANIMALS

THE writer has called attention in several papers[1] to the existence of axial gradients in rate of metabolism in planarians and other forms and their significance in relation to polarity. During the past summer in the course of other work at Woods Hole the opportunity presented itself to examine various forms belonging to different groups and various embryonic and larval stages for the existence of such gradients.

The method used was that of determining the relative susceptibility of different regions

[1] *Jour. Exp. Zool.*, XII., 1912; *Arch. f. Entwickelungsmech.*, XXXV., 1913; XXXVII., 1913.

of the body to certain narcotics and poisons, KCN, alcohol and ether being chiefly used. To concentrations of these and various other substances which kill within a few hours without permitting any acclimatization the susceptibility varies in general with the rate of metabolism, or of certain fundamental metabolic processes, *i. e.,* the higher the rate of these processes the greater the susceptibility and the earlier death or cessation of movement occurs.[2] Death in these reagents is usually followed very soon, often almost at once, by rounding, separation or disintegration of the cells, so that the time of death can be approximately determined by visible changes of this kind. Results obtained in this manner can be controlled by removing the animals from the solution at different periods and determining when recovery ceases to occur and experience has shown that these two methods of procedure give essentially similar results. In this way the following forms were examined.

In *Nereis virens* the regional susceptibility of developmental stages from the beginning of cleavage to the late trochophore was determined. In the early cleavage stages the micromeres are more susceptible to KCN 0.005 *m.* than the macromeres. They not only disintegrate before the macromeres when the eggs remain in the solution, but if the eggs are returned to sea water at the proper time the micromeres alone are killed and the macromeres recover and resume division, giving rise to defective larvæ.

At the stage when gastrulation is nearly completed the somatic plate region is apparently the most susceptible region of the embryo, and by return to water at the proper time it is possible to obtain larvæ which do not elongate posteriorly and do not form the three larval segments. If the embryos at this stage are left for a longer time in KCN before return to water, both somatic plate and some or all of the macromeres are killed and the intact portion consists of more or less of the ventral portion of pretrochal and post-trochal ectoderm with or without a part of the macromeres. Evidently the most susceptible regions at this stage are first the somatic plate, and second, the dorsal part of the pretrochal region and the macromeres.

In the developing egg of another annelid, *Chætopterus pergamentaceus,* the relative susceptibilities of different regions are much the same. In the early stages the animal pole shows the highest susceptibility and in later stages a second region of high susceptibility appears in the somatic plate. In still another polychæte, *Arenicola cristata,* the apical region and somatic plate of the young trochophores are the most susceptible regions. The early cleavage stages of this species were not obtained.

In *Nereis* and *Chætopterus* the region about the animal pole is clearly the region of greatest susceptibility, *i. e.,* of greatest metabolic activity in the early stages of development. Later the activity in this region becomes relatively less in *Nereis* as differentiation of the apical larval region advances and the somatic plate becomes the most active region of the egg. But in *Chætopterus* the apical region retains its susceptibility to some extent at the completion of gastrulation, and this region and the somatic plate appear as distinct regions of high susceptibility. In other words, at the beginning of development an axial metabolic gradient exists with the region of highest rate about the animal pole, but as development proceeds this gradient is altered from its primary simple form by the increase in activity of the cells which give rise to body segments and later by decrease in activity in the animal pole region.

In the egg of the sea urchin *Arbacia* in KCN 0.005 *m.* a distinct susceptibility gradient was observed during cleavage, death and disintegration beginning at one region of the egg and proceeding along an axis, but it was not possible to determine whether the region of highest susceptibility was always the animal pole, though in many cases it certainly was. In the later gastrula and prepluteus stages this simple gradient was complicated by the appearance of high susceptibility in the re-

[2] Child, *Jour. Exp. Zool.,* XIV., 1913.

gions where the arms were beginning to develop.

Since in *Nereis, Chætopterus* and *Arbacia* the different susceptibilities of different regions of the developmental stages make it possible to kill with more or less exactness certain parts of the embryo while other parts may recover and continue development, this method may prove of some value in further investigation of the regulatory capacities of the less active regions when isolated from the influence of the more active.

The adult forms of a number of species from various groups were examined for a susceptibility gradient. In the hydroid *Pennaria tiarella* with KCN 0.0025 *m.* and 0.005 *m.* such a gradient appears very clearly in the body of the hydranth, death and disintegration beginning at the distal end of the manubrium and proceeding proximally. A similar gradient exists in the medusa buds of this species. Besides this it was observed that the full-grown hydranths at or near the tips of stem or branches were in general more susceptible than the more proximal. This difference may be due to external factors such as the lower oxygen or higher CO_2 content of the water about the more proximal hydranths in consequence of the greater number of hydranths in a given area, but it seems more probable, in the light of various data concerning the polarity of plants, that this difference in susceptibility of distal and proximal hydranths is the expression of an axial gradient in the colony.

In several other species of hydroids examined at Woods Hole and at La Jolla, California, among them *Tubularia crocea* and *Corymorpha palma* the gradient in the hydranth body is similar to that in *Pennaria*.

The ctenophore *Mnemiopsis leidyi* shows a distinct gradient in susceptibility along each row of swimming plates. The susceptibility of these animals to KCN is very high and most experiments were made with KCN 0.0000375 *m.*—00005 *m.* Rhythmic movement of the plates ceases first at the central end of each row, *i. e.,* the end nearest the apical sense organ, and last at the peripheral end. Before movement has entirely stopped in the apical region the rhythm of the plates in the peripheral half or third of the row becomes different from the central rhythm, being usually more rapid and in some cases irregular or periodic. In two cases a perfectly distinct reversal in direction of the impulse was observed at the peripheral end of a row after movement at the central end had ceased. In this case the impulse started at the extreme peripheral end of the row and traveled some distance in the central direction, finally dying out. This continued for an hour or more before movement at the peripheral end ceased.

This susceptibility gradient is undoubtedly a gradient in the nerve and not in the plates themselves, for the plates do not die in KCN until long after rhythmic movement ceases, and as long as they remain alive direct contact stimulation of single plates produces slight movements of the plate stimulated. However, a slight susceptibility gradient does exist in the plates themselves as is evident from the fact that the plates at the central end of the nerve die first and death proceeds peripherally. The time of death is readily determined, for when they die the plates lose their interference colors and become white and opaque.

As regards the general ectoderm of *Mnemiopsis,* it is difficult to determine the time of death accurately, but observations thus far indicate that the disintegration of the ectoderm proceeds from the apical region.

During the course of my observations on susceptibility gradients Dr. Tashiro called my attention to his discovery of a quantitative gradient in CO_2 production in the claw nerve of the large spider crab, *Libinia canaliculata:* this is a long nerve which readily separates into small strands and is therefore favorable for observation of any structural changes which might occur in connection with death in solutions of narcotics. The nerve is mixed but is believed to consist largely of efferent fibers.

Since there is some evidence in the work of various authors that a gradient of some sort exists in the nerve, the attempt was made to

determine whether a gradient would appear in the structural death changes. A number of nerves were observed in various concentrations of KCN from 0.001 *m.* to 0.01 *m.* In these solutions the fibrillæ become after a time irregular in outline and more or less varicose so that the strand appears more or less granular instead of fibrillar like the fresh living nerve. The preparations showed some indications of the progression of the change from the central to the peripheral end of the nerve, but the changes were so slight that the possibility of a subjective factor being concerned could not be neglected. In the attempt to obtain more distinct structural death changes other narcotics were used, and it was found that in ethyl ether the fibrillation almost completely disappeared and the strands became very distinctly granular in appearance in consequence of irregular swelling and varicosity of the fibrils. In 1 per cent. ether or somewhat lower concentrations these changes occur, slowly requiring several hours for completion, and a very distinct gradient in their occurrence is visible. The change from fibrillar to granular appearance begins at the two ends of the nerve very soon after it is brought into the solution, and a distinct gradient in this change can be seen extending a few millimeters peripherally from the central end and a shorter distance centrally from the peripheral end. This first change remains limited to the two terminal regions of the nerve and is undoubtedly associated with the stimulation and injury resulting from severing the nerve at these two points.

Later, however, the change begins to progress along the nerve from the central toward the peripheral end, but the change at the peripheral end progresses only very slowly or not at all in the central direction. From this time on a distinct gradient in the change is visible until it has progressed along the whole length of the nerve. Except in the terminal region adjoining the peripheral cut end the death change always progresses in the peripheral direction. The peripheral third of the length may be entirely unchanged at a time when the central third or more has completely lost its fibrillar appearance. When long strands are so arranged that central and peripheral regions are side by side in the same field of the microscope the differences between the two regions are very striking. If the nerve is crushed or injured at any point short gradients appear on both sides of the injury, but do not extend to any great distance before the general change reaches this region in its progress peripherally.

The existence of this centro-peripheral gradient in the death changes of the nerve fiber in narcotics must mean that a gradient of some sort exists in the living nerve and if the action of the narcotics is of the same character here as in other cases we must conclude that this gradient is associated with metabolism and that the rate of metabolism or of certain metabolic processes is in general higher at the central end and decreases peripherally in this nerve.

That metabolic gradients occur very widely if not universally, at least during the earlier stages of development in axiate organisms and structures, is evident from the data of embryology. The so-called law of antero-posterior development must be the expression of an axial metabolic gradient. And as regards plants there is a large body of evidence which indicates that the vegetative tip possesses a higher rate of metabolism than other regions of the same axis. Even in the unicellular body of the ciliate infusoria and in various other cells which show a morphological polarity the writer has observed a susceptibility gradient. In view of the facts it is impossible to doubt that such gradients are in some way closely associated with polarity in organisms, and various lines of experimental evidence which can not be considered here indicate that they constitute the dynamic basis of polarity. There are, moreover, many facts which suggest that the establishment of a gradient of this kind is the first step in individuation in axiate organisms.

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